Dust Telescope on the Lunar Surface

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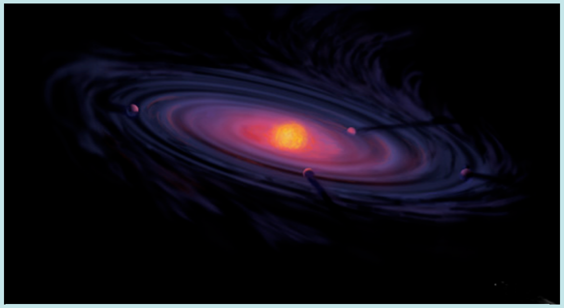
Overview

- Motivation: Science *from* the surface of the Moon
  - Detection of interstellar dust
  - Composition of interstellar dust
  - Interaction with the interplanetary magnetic field
- Instrumentation
- Summary

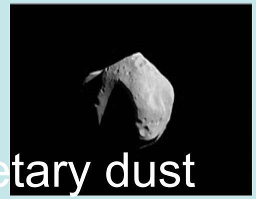
The Interstellar Dust Story (dust to dust)

Protoplanetary disk



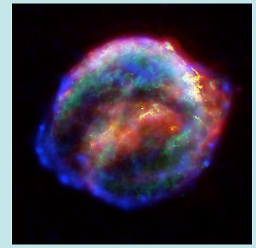
Star + planetary system

Comets, asteroids

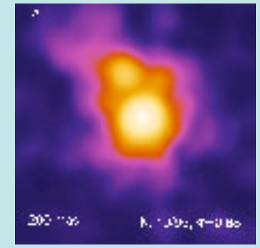


Interplanetary dust

Dust factories



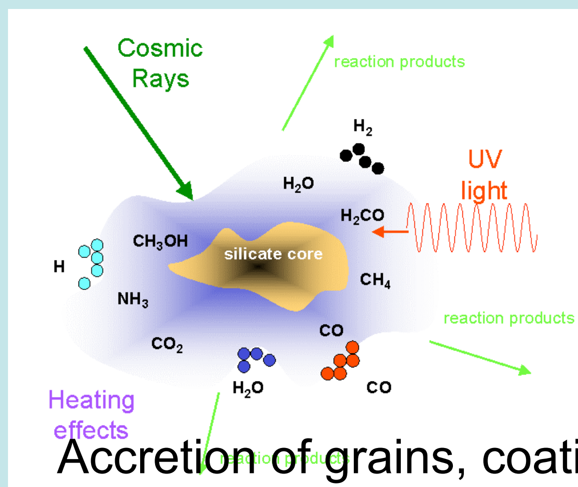
Supernova explosions



AGB stars

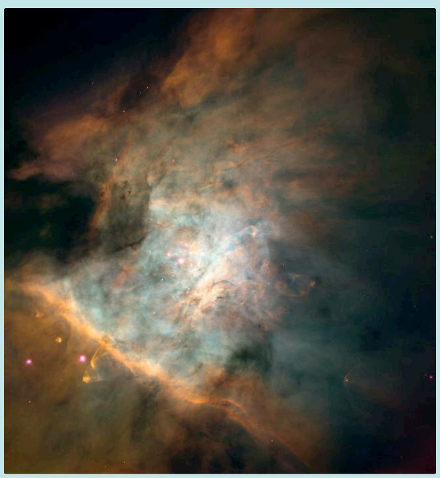
Diffuse interstellar medium

Dense molecular cloud



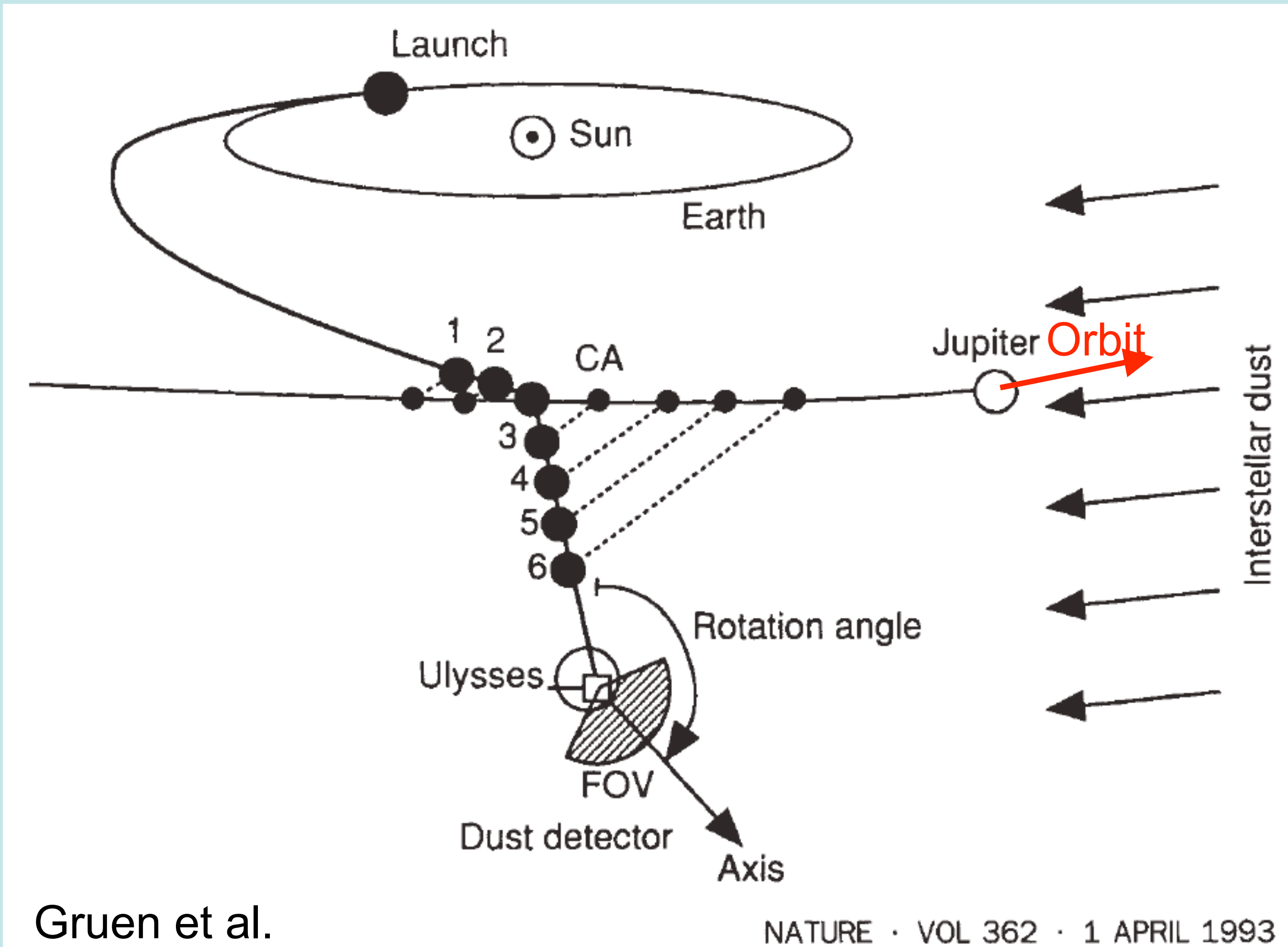
Accretion of grains, coating by organics and ices

Stellar nebula



Formation of new stars

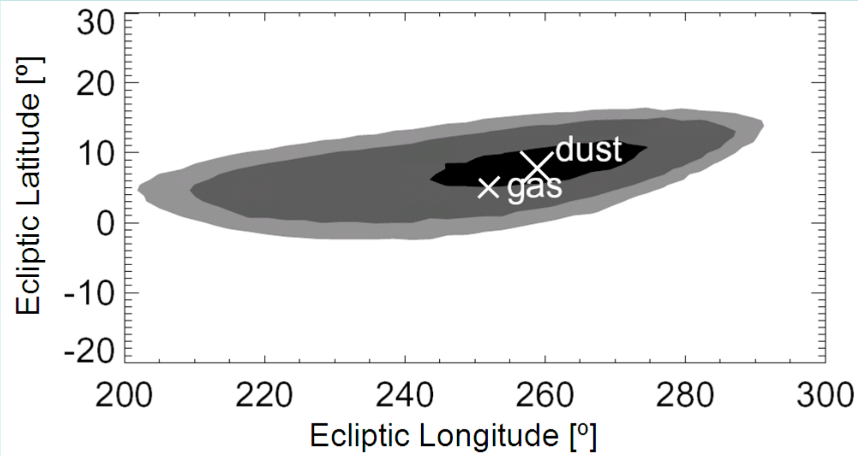
Ulysses: discovery of interstellar dust within the solar system



Interstellar dust identified by: Retrograde orbit, High impact velocity (> 26 km/s)

Properties of the interstellar dust flow

Flow direction



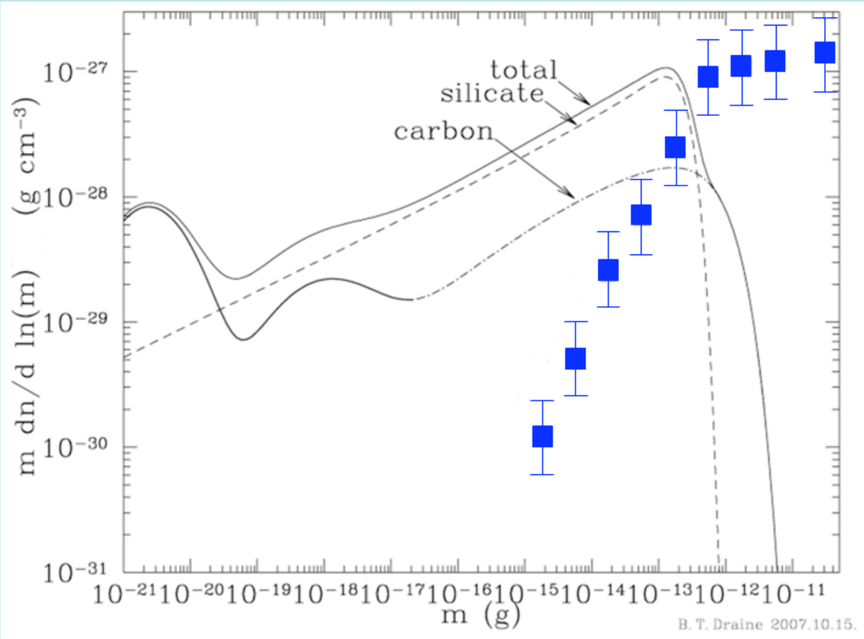
Frisch et al, 2007

ISD flux (at 1 AU)

$\underline{J \approx 1.5 \times 10^{-4}\ m^{-2}s^{-1}}$

(approx: 13 particles per m² per day)

Mass density distribution



The mass density distribution per log mass interval *m*d*n*/d*ln*(*m*) measured by Ulysses (Landgraf et al., 2000) shows an astonishing excess of large grains over the predictions of models based on wavelength-dependent extinction observations (continuous lines). This represents a challenge to our current understanding of the extinction measurements, as well as the chemistry of diffuse interstellar clouds.

Properties of the interstellar dust flow

Forces

$F_L = q(\mathbf{E} + \mathbf{v}\mathrm{x}\mathbf{B})$

B - interplanetary

F_G – Sun's gravitational force (~a^3)

F_R – Radiation force (~ a^2)

$\beta = F_R/F_G$

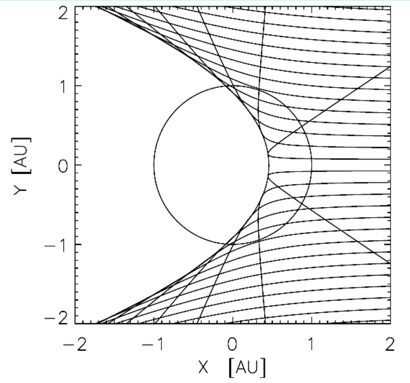
<u>Cases</u>

(r < 5 nm) – tied to interstellar **B**

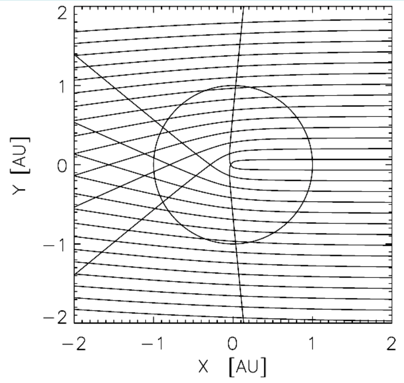
(r < 200 nm) – cannot reach Earth

(r ~ 300 nm) – β >1

Dust dynamics at 1 AU



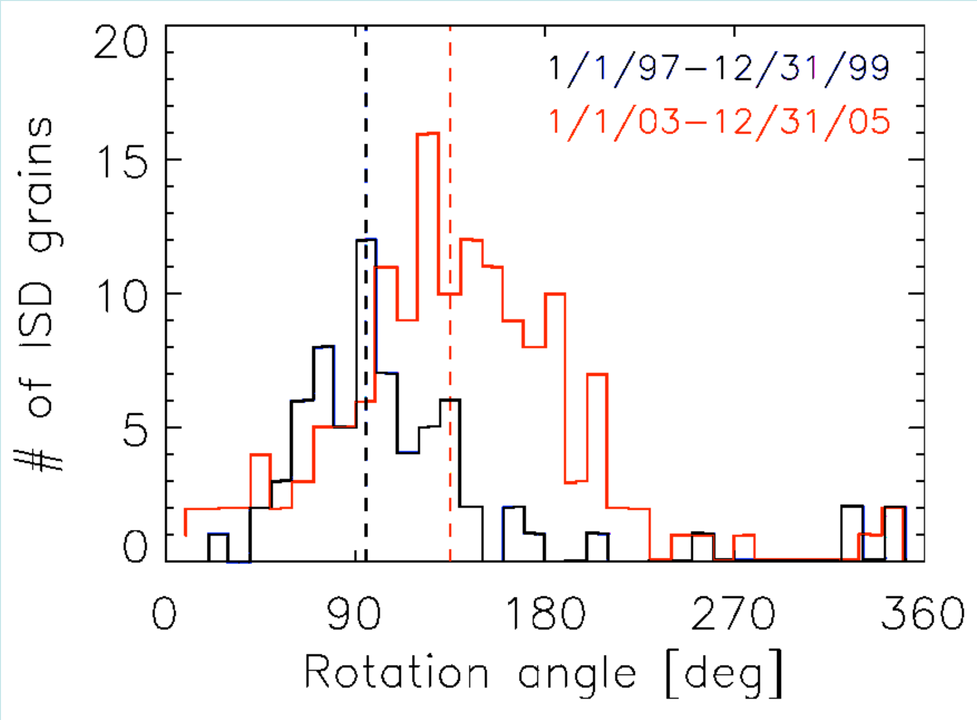
m = 3x10^{-13} g
a = 0.3 μm
β = 1.2



m = 1.2x10^{-12} g
a = 0.5 μm
β = 0.8

Solar cycle effect

The change in the direction of ISD flow is due to solar cycle effects



Krueger et al, 2007

- Ulysses measures direction only by statistical means
- B field changes with solar cycle (22 years period)
- ~ 20 years flight time for dust to reach the Earth from the

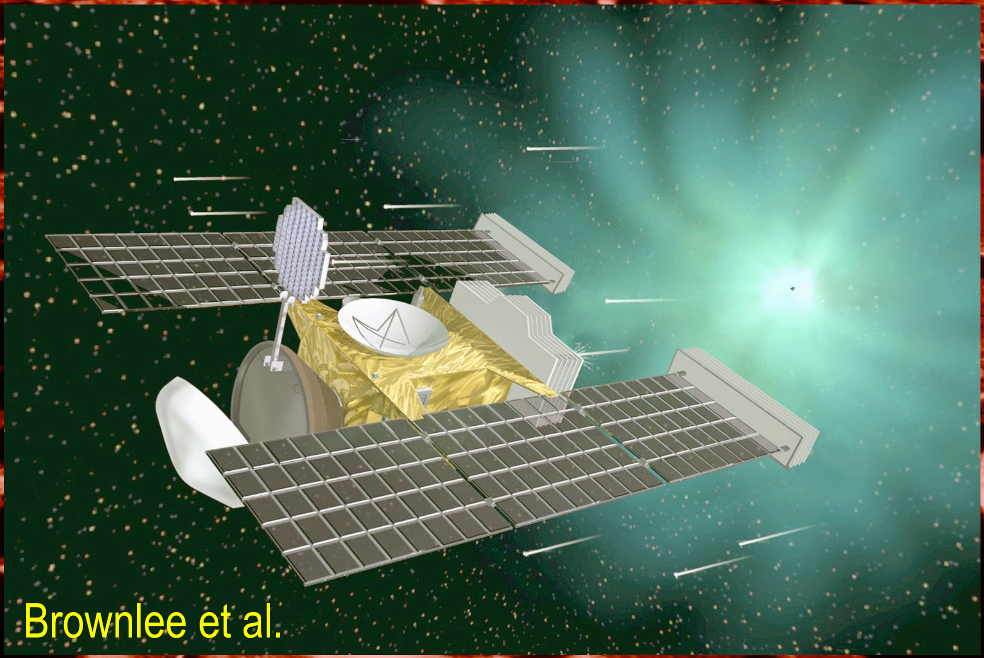
Accurate trajectory measurement:

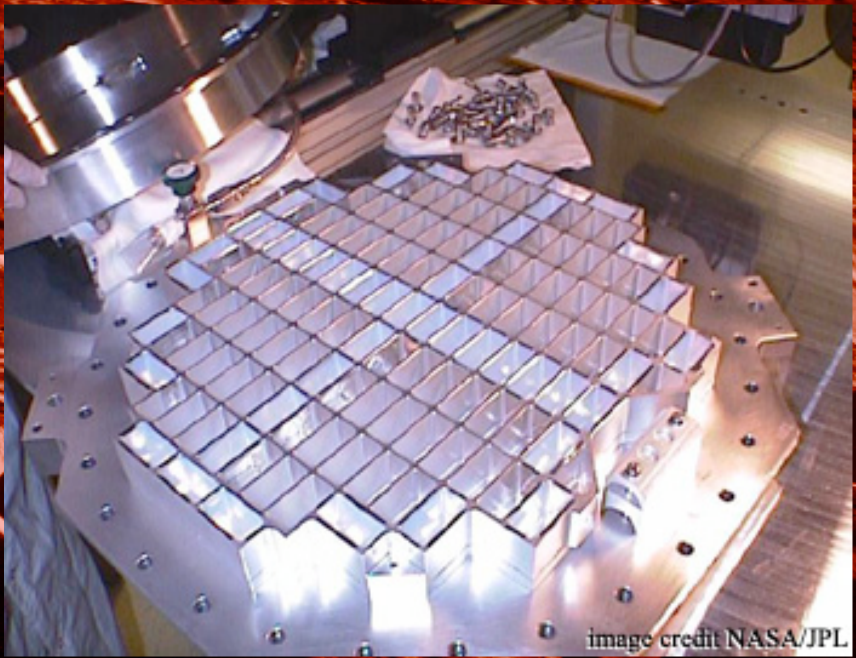
- Probes the IMF
- Provides source of ISD

ISD composition

- ISD grains contain most of the refractory elements (Fe, Mg, Si, Al, Ca)
- Significant content of C and O
- Organic material (PAH)
- Ices: H_2O, CO, CO_2, CH_3OH (in dark clouds)
- **Mathis et al. (1996)**
  a) Small graphite grains
  b) Silicate grains
  c) Composite grains containing carbon, silicates and oxides
- **Li & Greenberg (1997)**
  a) Large grains with silicate core and organic refractory mantle
  b) Small carbonaceous grains
  c) Very small grains (or large clusters) of PAH
- **Draine & Li (2007)**
  a) Amorphous silicate grains
  b) Carbonaceous grains including small PAH

Stardust ISD sample return
Preliminary analysis started



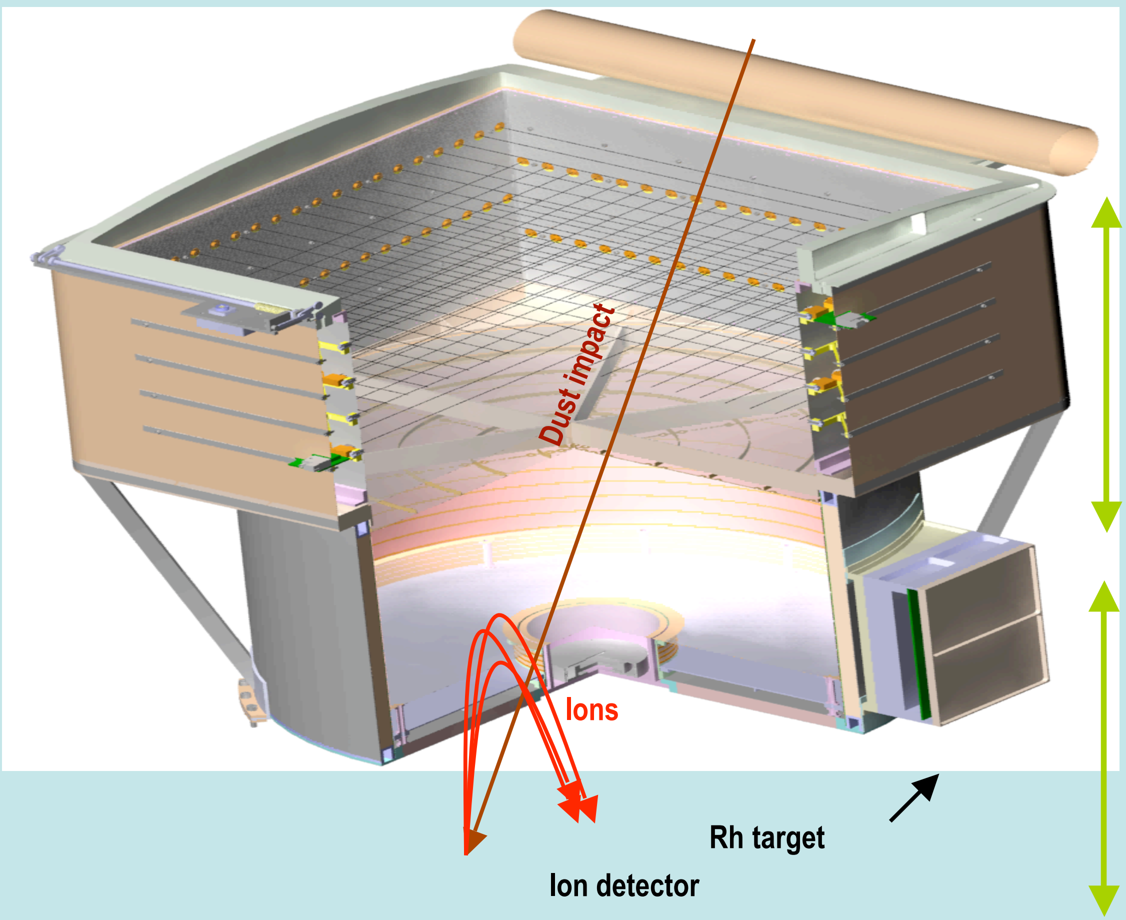


- 195 days of sample collection
- Estimated 60 grains collected
- Heating and abrasion effects are likely severe
- Locating tracks and extraction are very challenging

Science objectives:

- **A1**: Explore the mass, chemical and isotopic composition distributions of ISD and Interplanetary (IDP) grains
- **A2**: Verify the Ulysses observations of the unexpectedly large flux of big ($m > 10^{-13}$ g) ISD grains
- **A3**: Validate remote sensing observations by in-situ measurements of the composition of ISD grains
- **A4**: Explore the connection between ancient ISD found in meteorites to that of ‘fresh’ inflowing ISD grains
- **H1**: Explore the influence of the solar cycle on the variability of the flow direction of ISD

In-situ Instrumentation: Dust Telescope



Target area: ~ 0.1 m^2 (approx 1-2 impacts / day)

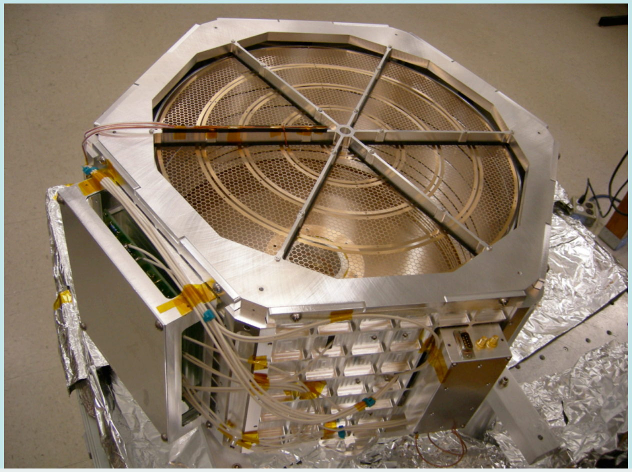
Z. Sternovsky

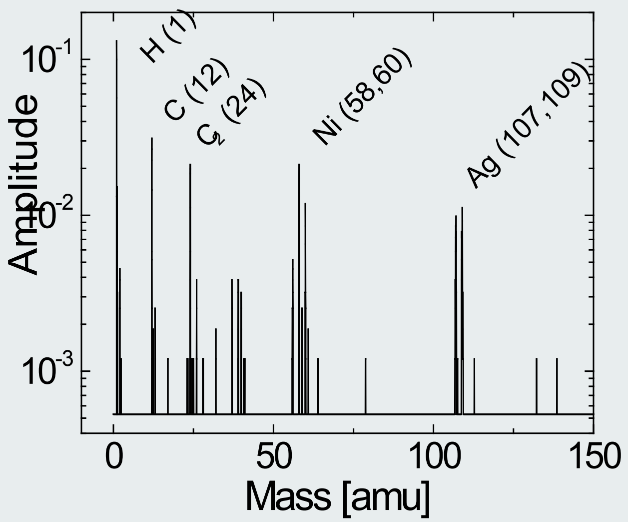
Dust Trajectory Sensor
Measures the velocity vector with high precision

Large Area Mass Analyzer
Measures the elemental composition

Dust Telescope prototypes

Large Area Mass Analyzer (LAMA)

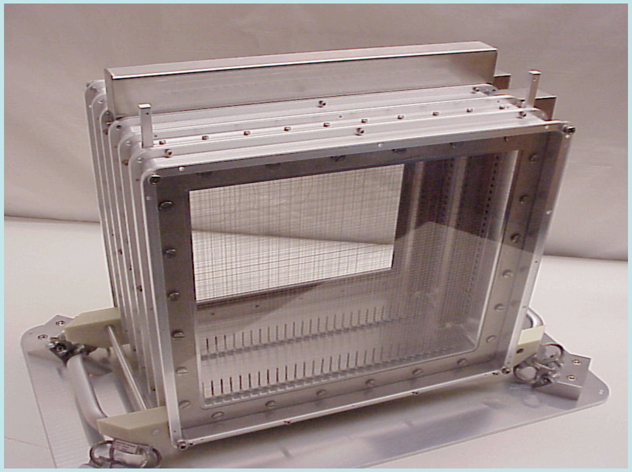




Sternovsky et al, 2007

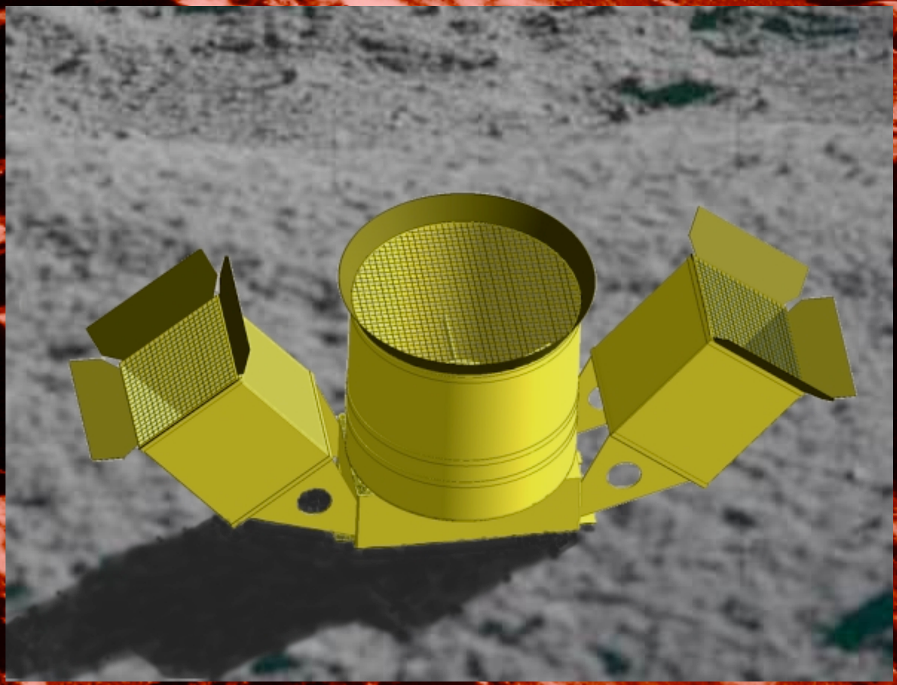
LAMA mass spectrum, 30 km/s Ni dust on Ag surface (m/dm = 200)

Dust Trajectory Sensor (DTS)



Trajectory reconstruction, velocity < 1%, direction < 1º precision

Why from the Moon?



- Moon is a good platform for Dust Astronomy
- The number of ISD impacts on the Moon's surface is comparable to the impacts of interplanetary dust
- Instrumentations compatible with other dust detectors:
  - Interplanetary dust impacts
  - Secondary ejecta detectors
  - Slow moving dust

Summary

"*All of us are truly and literally a little bit of stardust.*" – William A. Fowler

- Interstellar dust (ISD) impacts the Moon!
- Astrophysics and Heliophysics science goals
- Advanced instrumentation is ready